Japan/East Sea Air-Sea Interaction and Meteorology: Boundary-Layer Structure and Model Validation

Carl A. Friehe and Djamal Khelif
Departments of Mechanical Engineering and Earth System Science
University of California, Irvine
Irvine, CA 92697-3975
phone: (949) 824-6259 fax: (949) 824-2249 email:cfriehe@uci.edu

Award #: N000149910205
http://wave.eng.uci.edu

LONG-TERM GOALS

The long-terms goals of the research are to understand and parameterize the physics of air-sea interaction and the marine boundary layer over a wide spectrum of weather and ocean conditions.

OBJECTIVES

The main objectives of this effort are to study the air-sea interaction under the extreme conditions of cold-air outbreaks over the JES during winter. We are primarily interested in *(i)* the determination of boundary-layer structure *(ii)* the measurement of momentum, heat and water vapor (latent heat) air-sea fluxes and their spatial variability *(iii)* parameterization of these fluxes and *(iv)* model validation using observations.

APPROACH

We instrumented the Navy CIRPAS Twin Otter research aircraft with wind, temperature, humidity, IR sea temperature and aircraft motion and navigation sensors. High quality turbulence and meteorological measurements from thirteen aircraft flights over the JES in February 2000 were obtained. The bulk of the measurements were made inside the "Flux Center" (41-42.5N, 131.5-133.5E, Kawamura and Wu, 1998) an area off of Vladivostok characterized by enhanced winds and surface fluxes due to the flow of cold and dry Siberian air channeled through the orographic gap near Vladivostok. Three basic research goals were addressed with different flight patterns: *(i)* Flux Mapping: after transit to the ``Flux Center" south of Vladivostok, the surface-layer fluxes were mapped in a grid pattern at 100 feet with soundings to 5000 feet; *(ii)* Internal Boundary-Layer Growth: after transit to the "Flux Center" south of Vladivostok, a line of soundings from 100 to 3000-5000 feet was flown following an approximate streamline across the JES (five-minutes flux legs were flown at 100 feet between soundings); and *(iii)* Flux Divergence: after transit to the ``Flux Center" south of Vladivostok, a vertical stack pattern was flown to determine the flux divergence profile in the boundary layer.

WORK COMPLETED

For the purpose of redundancy, the data were recorded simultaneously on two computers aboard the aircraft. We completed the processing of the data from both systems. On the few occasions where one of the computers experienced problems we merged data from the two systems to ensure no data were lost. The resulting processed data set is about 9 GB in size.

The incorporation of the correction to the aircraft static pressure known as "static pressure deficit" obtained from "trailing cone" flights prior to JES greatly improved the horizontal wind measurements. This correction is specific to the Twin Otter and should be applicable for future projects.

The data analysis is well underway. So far we analyzed in detail five flights that including the time periods on which COAMPS model was run by Prof. Q. Wang of USNPGS. Mean meteorological data as well as turbulent fluxes of momentum and latent and sensible heats were obtained from the low level runs. Aircraft sounding data were also analyzed and provided a good description of the vertical structure of the MABL.

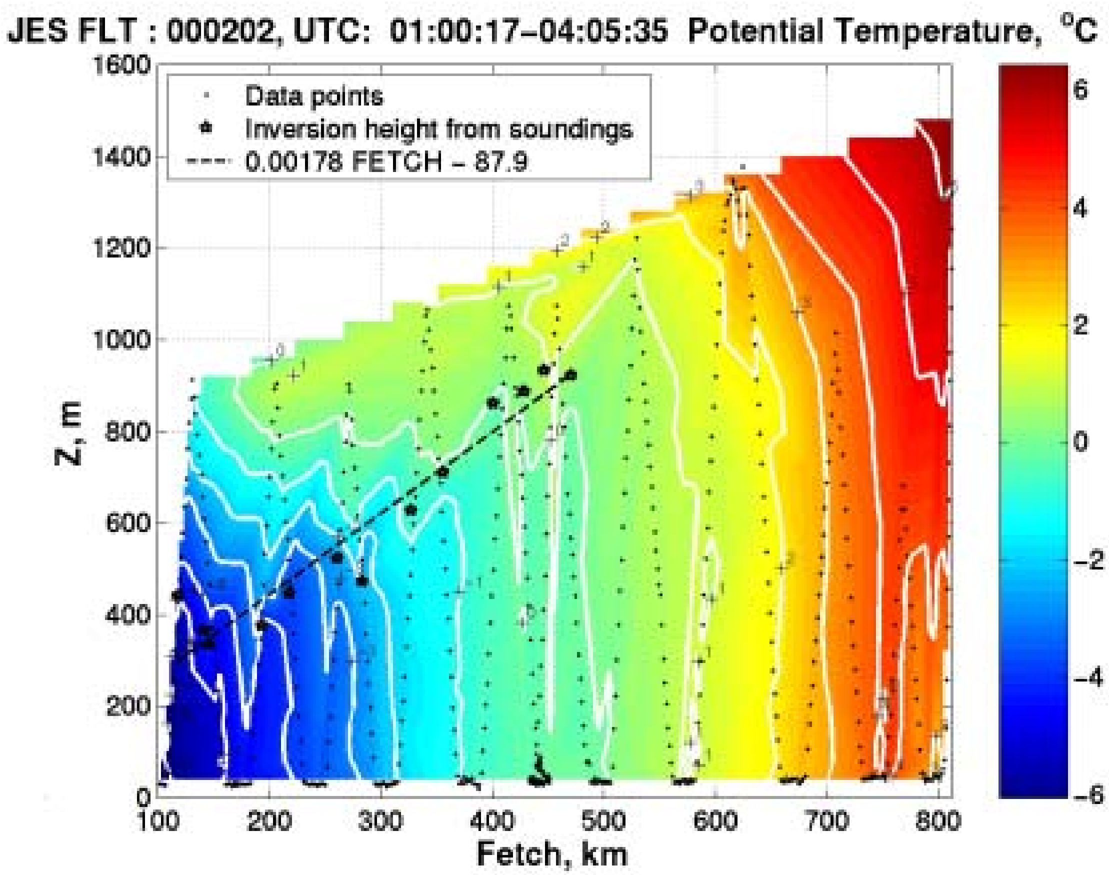

Figure 1 Vertical stream-wise cross-section of the MBL over JES showing the structure of potential temperature for Feb 03, 2001 at 01:00:17-04:05:35 UTC. The dotted lines represent the aircraft elevation as a function of distance from the coast (fetch). The dashed line is the least–square linear fit of internal boundary layer height to fetch.

RESULTS

An example of the MABL vertical structure of potential temperature obtained from a sounding flight pattern (flight 000202) for the Feb 03, 2001 at 01:00:17-04:05:35 UTC period is given in Fig. 1. The saw-tooth sounding pattern is indicated by the dotted line. Similar maps showing the vertical structure of humidity and wind speed reveal that colder, dryer and faster moving air close to Vladivostok picks up moisture and heat as it is advected along the streamline. The winds decayed after 250-350 km into the JES and picked up while approaching Honshu.

Internal Boundary Layer (IBL) heights were determined from the individual soundings for a moderate cold-air outbreak day (flight 000202) and a stronger case day (flight 000217) where the observed maximum surface winds just south of Vladivostok were 12 m s^{-1} and 17 m s^{-1}, respectively. The linear least-squares fit of these IBL heights to the square root of the fetch is given in Fig. 2. The fit is very reasonable especially for the stronger winds day (flight 000217). The growth rate of 1.82 $m^{1/2}$ found for flight 000202 is close to the 1.91 $m^{1/2}$ found near shore by Hsu (1986).

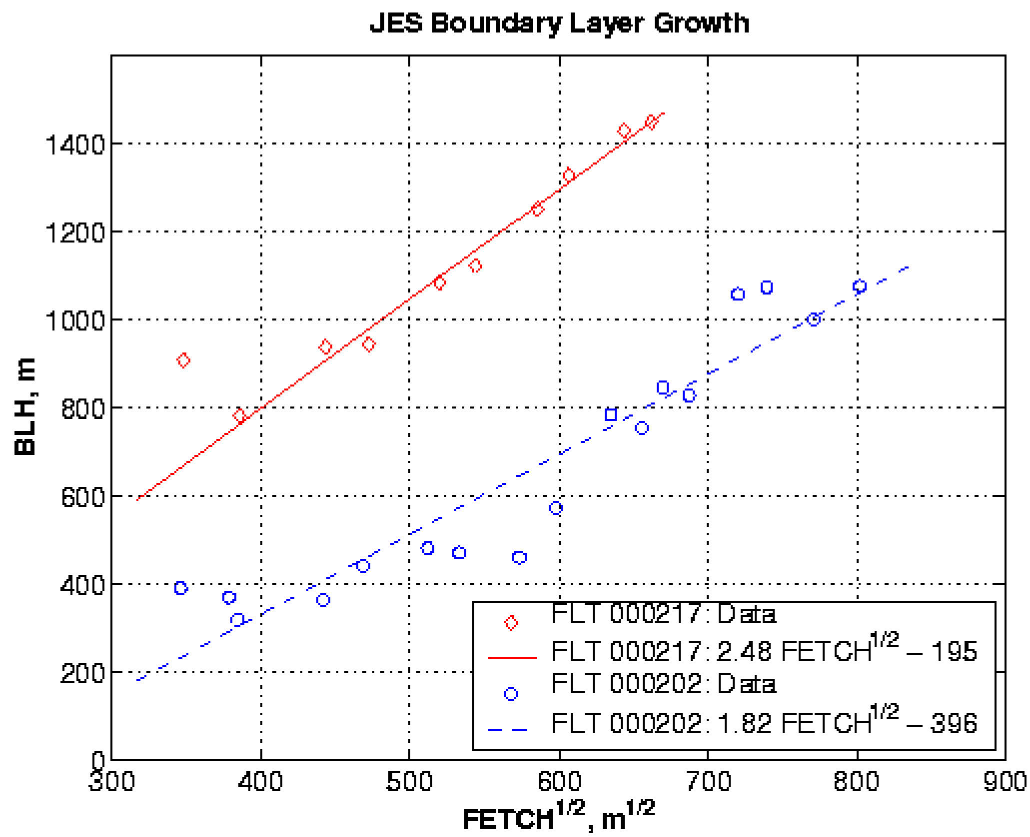

Figure 2. Internal Boundary layer growth with square root of fetch for flights 000202 and 000217.

Eddy correlation fluxes for flight 000217 were estimated along the 5-6 minutes deck level runs flown at roughly 40 m between each sounding pair along an approximate streamline. The results are summarized in Fig. 3 for along-wind momentum, sensible heat and latent heat fluxes. It can be observed that the combined fluxes are the largest inside the "flux center". This is in agreement with Kawamura and Wu (1998) who used only satellite (NSCAT) and ECMWF results. They fluxes decreased considerably (more than 50% for sensible heat) immediately outside the flux center. They started to increase again past the 40oN which corresponds roughly the location of the SST front. Both latent and sensible heats fluxes increased greatly in the vicinity of Honshu as a result of the relatively warmer water and the island's orography.

One particularity of the wintertime JES is that the temperature difference between the air and the sea surface remains fairly the same (8-9 oC) across the JES. This is due to the SST north-south gradient across the JES which seems to balance the increase in air temperature as the air mass crosses the JES.

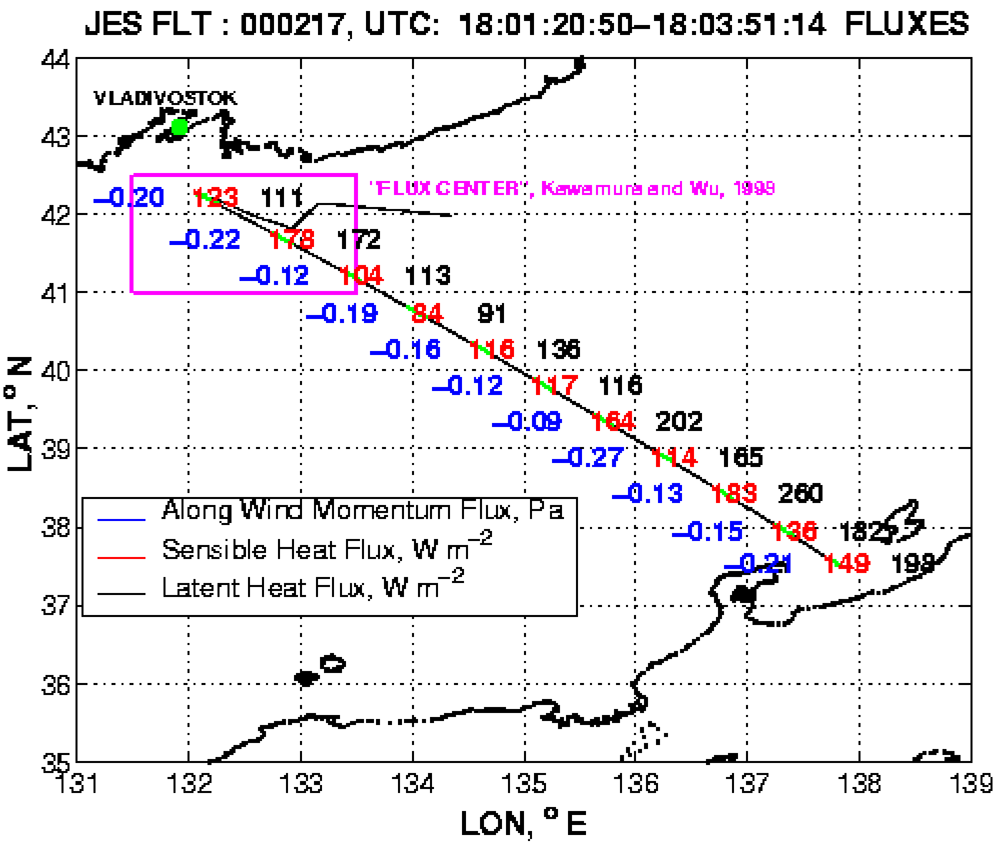

Figure 3 Surface turbulent fluxes of momentum (blue), sensible heat (red) and latent heat (black). The units are Pa, W m^{-2} and W m^{-2} respectively.

Prof. Qing Wang (2000) of USNPGS has run the COAMPS model for Feb 03 200 and found it predicted reasonably well the mean quantities and boundary-layer growth but overestimated the fluxes. We are planning exhaustive comparisons between our observations and COAMPS results to investigate further these discrepancies.

IMPACT/APPLICATIONS

The high-quality turbulence and meteorological aircraft data are the first measurements to provide good spatial (both horizontal and vertical) coverage of the boundary layer over the JES in cold-air outbreaks conditions. Their impact is to improve our understanding and parameterizations of air-sea fluxes and boundary-layer structure in extreme weather conditions. Their use as input and validation of JES mesoscale models such as COAMPS and MM5 will enhance the accuracy of these models.

TRANSITIONS

The same instrumentation we developed for the JES experiment has been used on the CIRPAS Twin Otter in the Rough Evaporation Duct (RED) experiment we just completed. The calibration maneuvers performed on each RED research flight will allow us to obtain an even better calibration of the wind measurement system. We are planning to use the new calibration results on our upcoming reprocessing the JES data set. Other recent Twin Otter projects where our instrumentation was used are DEC (1999), SHOWEX (1999) and HALO (2001).

RELATED PROJECT

A DURIP instrumentation grant was also obtained during the first year of this grant period to purchase the major equipment for the CIRPAS Twin Otter aircraft.

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